CAN 1011: Data Communication

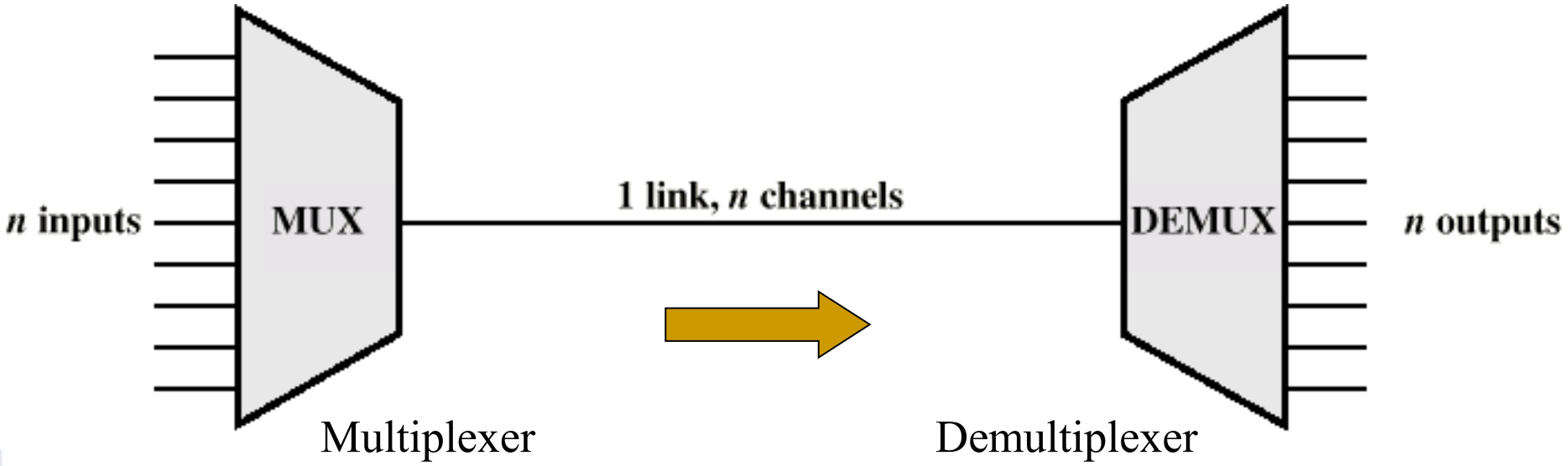
- Multiplexing

Contents

- Three Multiplexing Techniques
  - Frequency Division Multiplexing (FDM)
  - Time Division Multiplexing (TDM)
  - Code Division Multiplexing (CDM)

Introduction

- Multiplexing: A generic term used when more than multiple source share the capacity of one link
- Objective is to achieve better utilization of the link bandwidth (channel capacity)



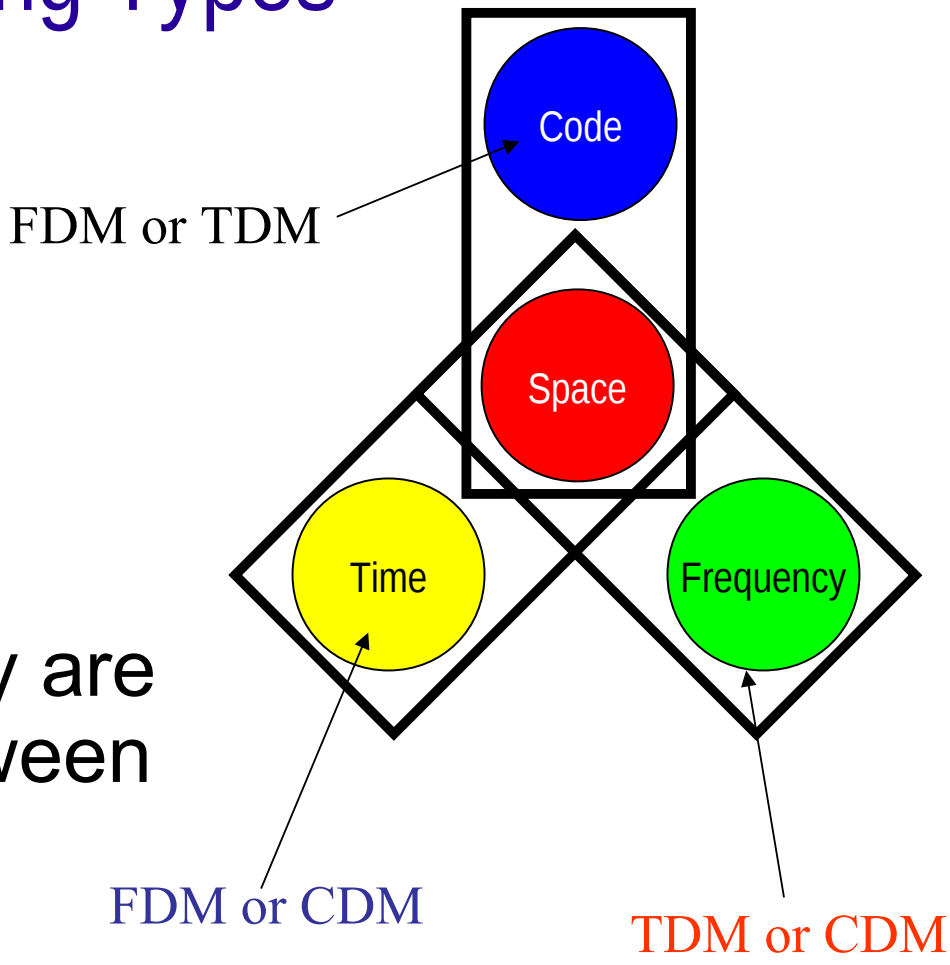
Motivation

- High capacity (data rate) links are cost effective. i.e. it is more economical to go for large capacity links
- But requirements of individual users are usually fairly modest…e.g. 9.6 to 64 kbps for non intensive (graphics, video) applications
- Solution: Let a number of such users share the high capacity channel (Multiplexing)
- Example: Long haul trunk traffic:
  - High capacity links: Optical fiber, terrestrial microwaves, etc.

  carrying large number of channels between cities over large distances

Multiplexing Types

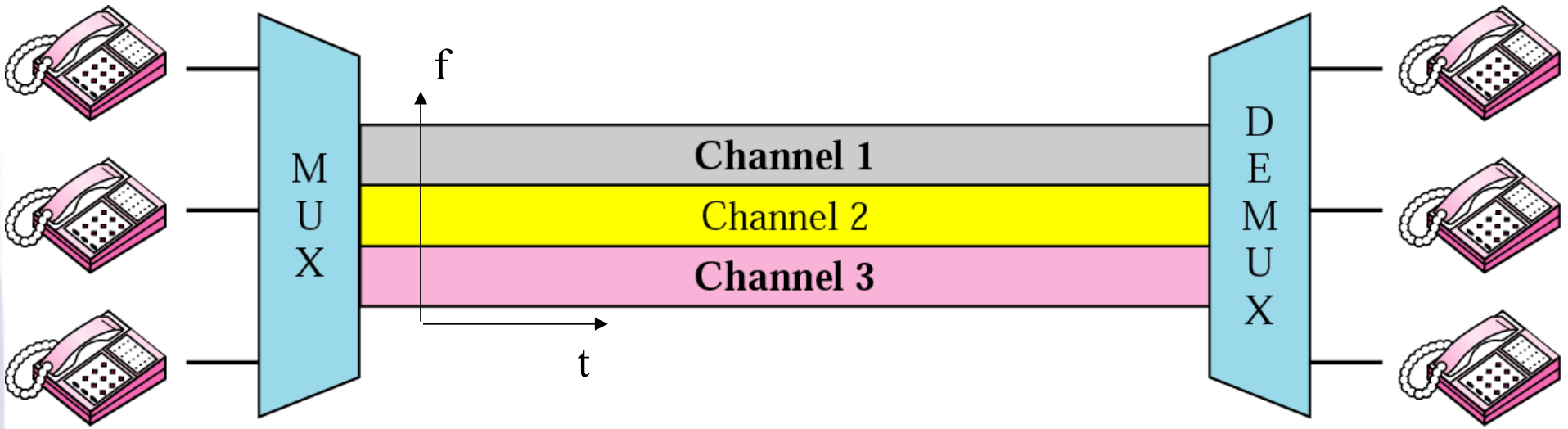
- Our three resources:
  Time Frequency Code
- Our channels must be separated in at least one resource
- The resource in which they are separated is "divided" between them:
  - CDM: Separation in code
  - TDM: Separation in time
  - FDM: Separation in frequency



To use the same circuit (line)
i.e. sharing space:
Use either TDM, FDM or CDM

Frequency Division Multiplexing (FDM) (With Analogue Signals)

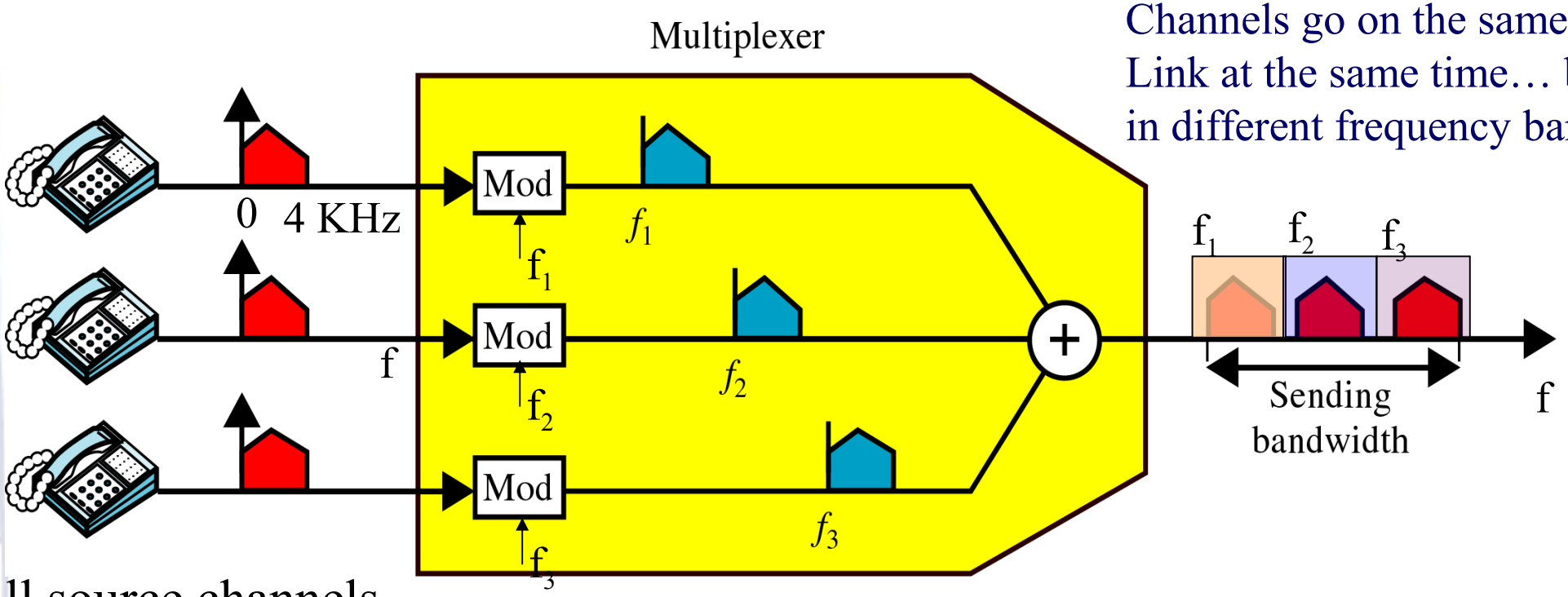
- Channels exist on the same line (space) at the same time:
- Must be separated in frequency!



FDM

- Useful bandwidth of medium exceeds required bandwidth of a channel
- Signal of each channel is modulated on a different carrier frequency f_c
- So, channels are shifted from same base band by different f_c's to occupy different frequency bands
- Carrier frequencies separated so that channels do not overlap (also include some guard bands)
- Disadvantage: Channel spectrum is allocated even if no data available for transmission in channel (rigid allocation)

FDM Multiplexing Process: Frequency-Domain View at TX

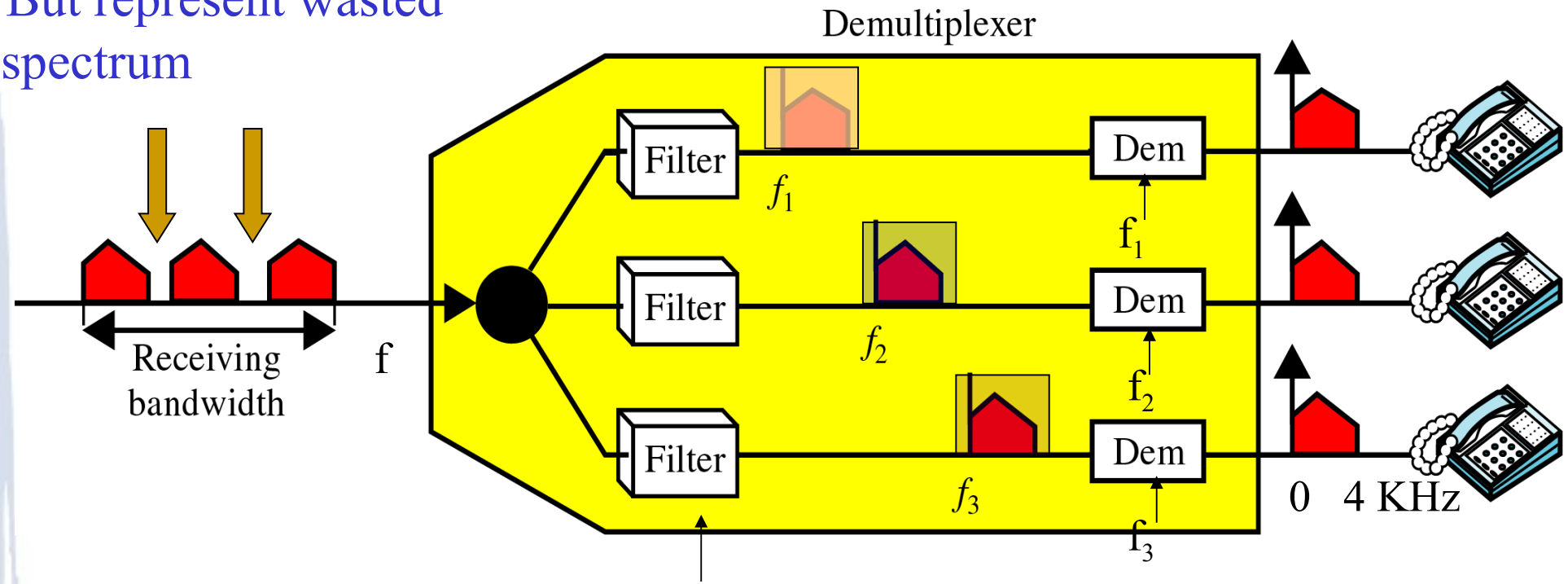


Channels go on the same Link at the same time… but in different frequency bands

All source channels are at (same) base band

FDM De-Multiplexing Process: Frequency-Domain View at RX

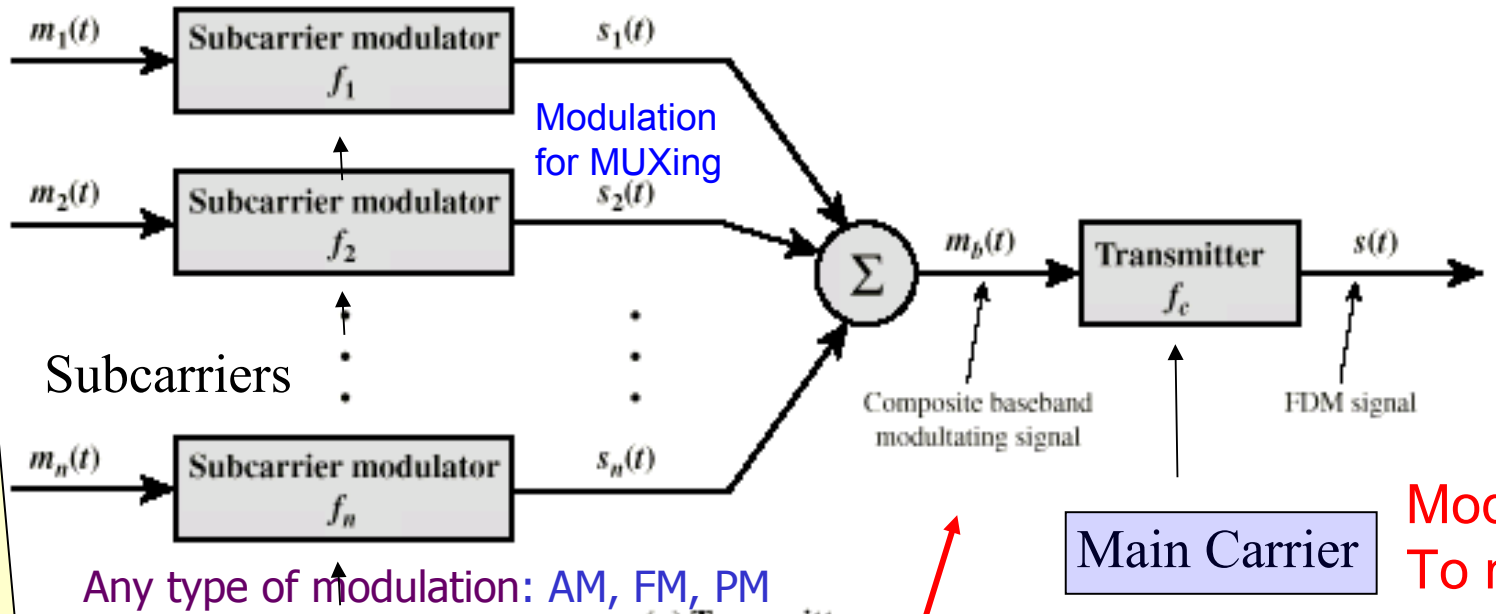
- Guard bands prevent channel overlap
- But represent wasted spectrum



Restoration at RX:
3 different pass-band filters, each bracketing a channel

All received channels restored to base band

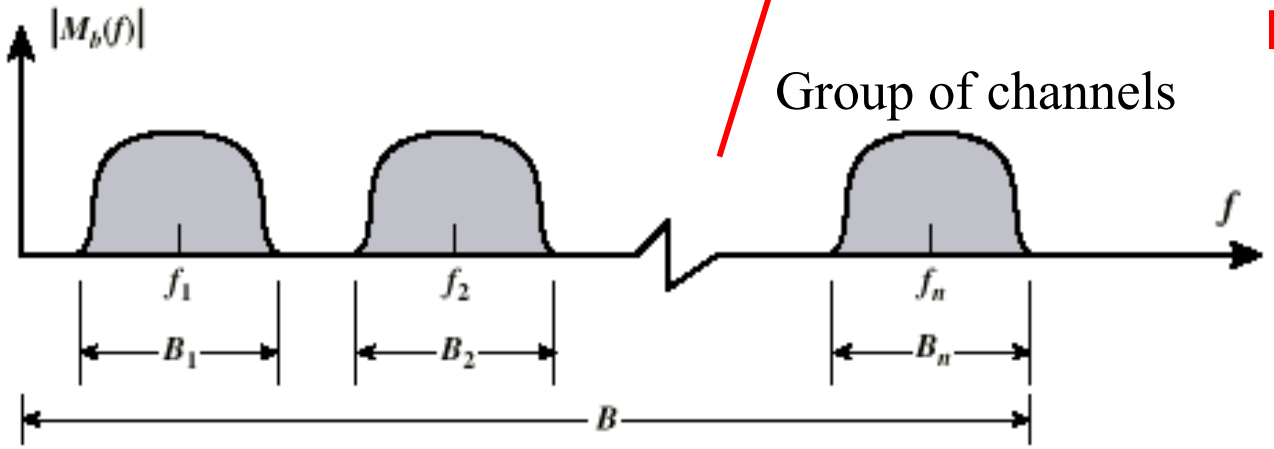
FDM System – Transmitter



(a) Transmitter

Individual base band channels

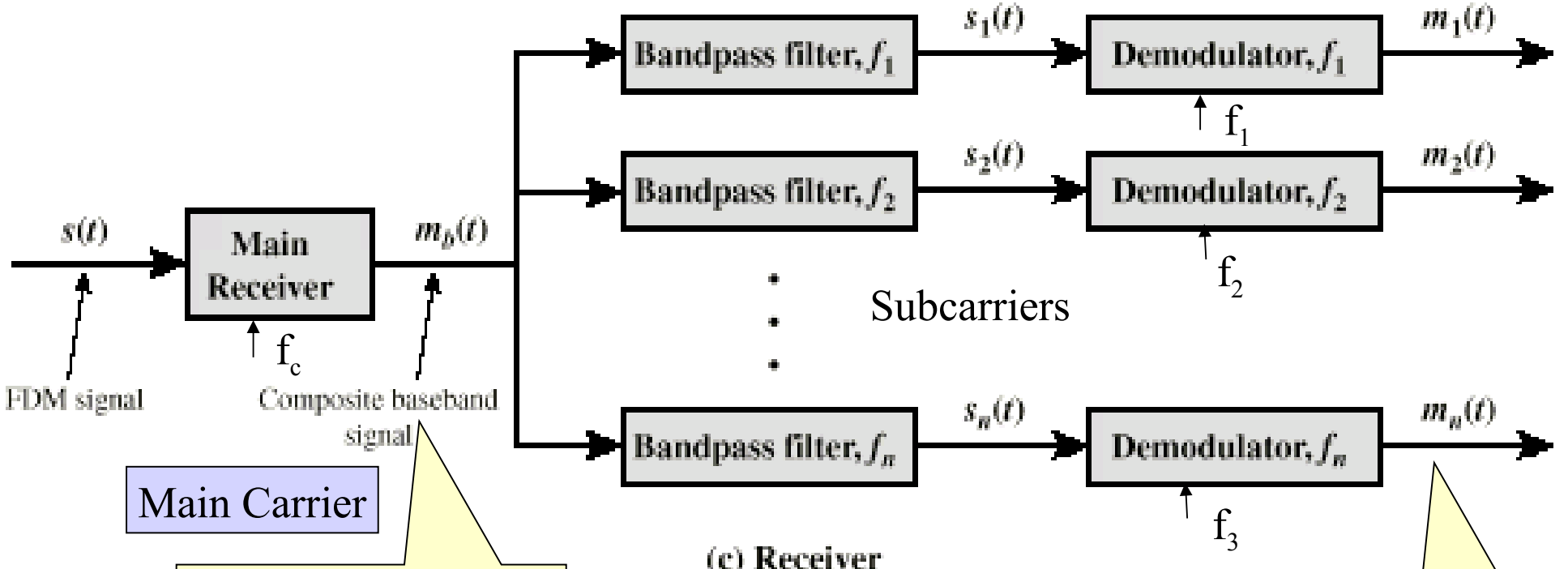
Group of channels



(b) Spectrum of composite baseband modulating signal

Modulation To meet Transmission Requirements

FDM System – **Receiver**



Composite base band signal $m_b(t)$ recovered

Individual base band channels recovered

FDM characteristic problems

- Two potential problems characterize FDM and all broadband applications
  - Crosstalk:

    - Due to overlap between channel spectra and the use of non-ideal filters to separate them

    → Use guard bands to reduce it

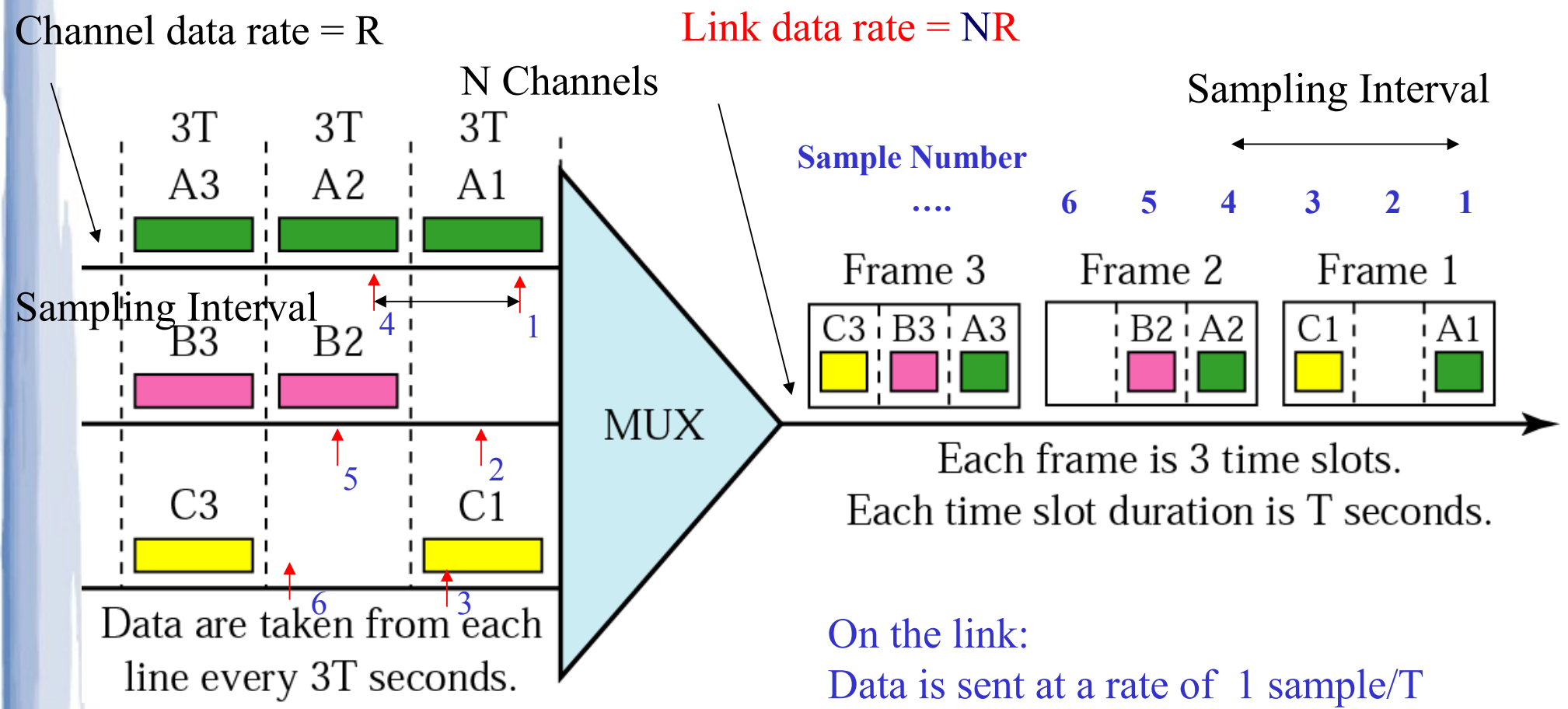
  - Inter modulation noise:

    - Nonlinearities in amplifiers 'mix' the MUXed channels

    - This generates spurious frequency components (sum, difference) which fall within channel BWs!

    - Limits the amount of amplification possible

TDM Frames



Channel sampling interval = 3T

For each channel, data rate is 1 sample/3T

On the link:

Data is sent at a rate of 1 sample/T

Data rate is 3 times the channel data rate

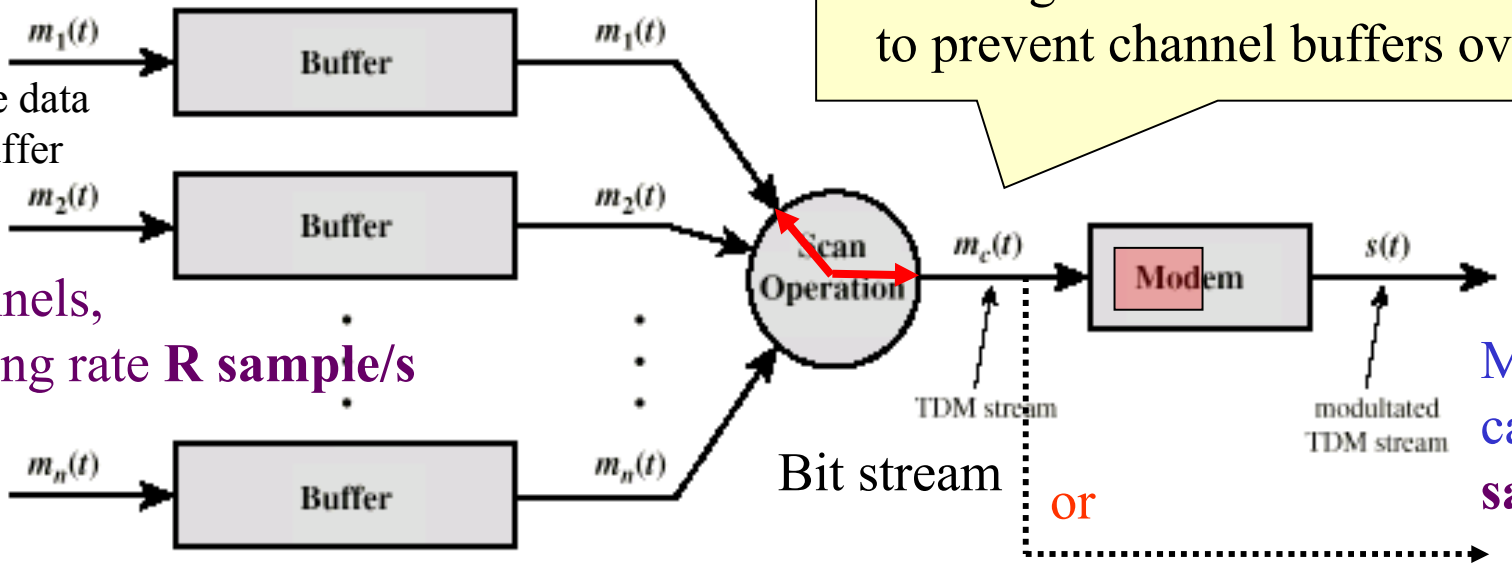
Time Division Multiplexing (TDM)

- Synchronous TDM: (Fixed channel scan arrangement)
  - Time slots pre-assigned to sources and fixed
  - Disadvantage: Time slots allocated even if no data available

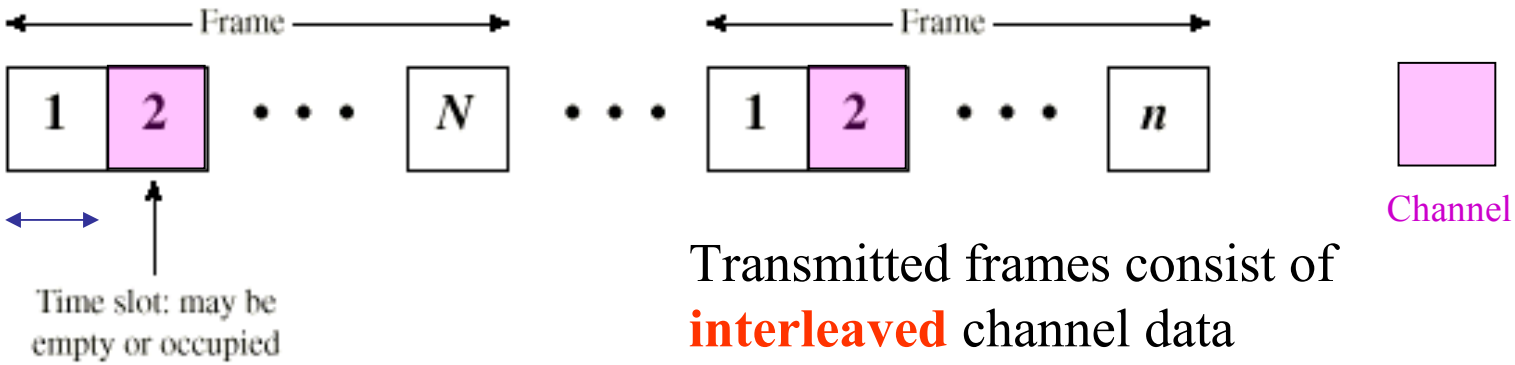
  (channel capacity waste, as with BW waste in FDM)
  - But simple to implement, e.g. No need to send ID of source channel
  - We could assign more than time slot per scan for faster sources- but on a permanent basis

Synchronous TDM – Transmitter

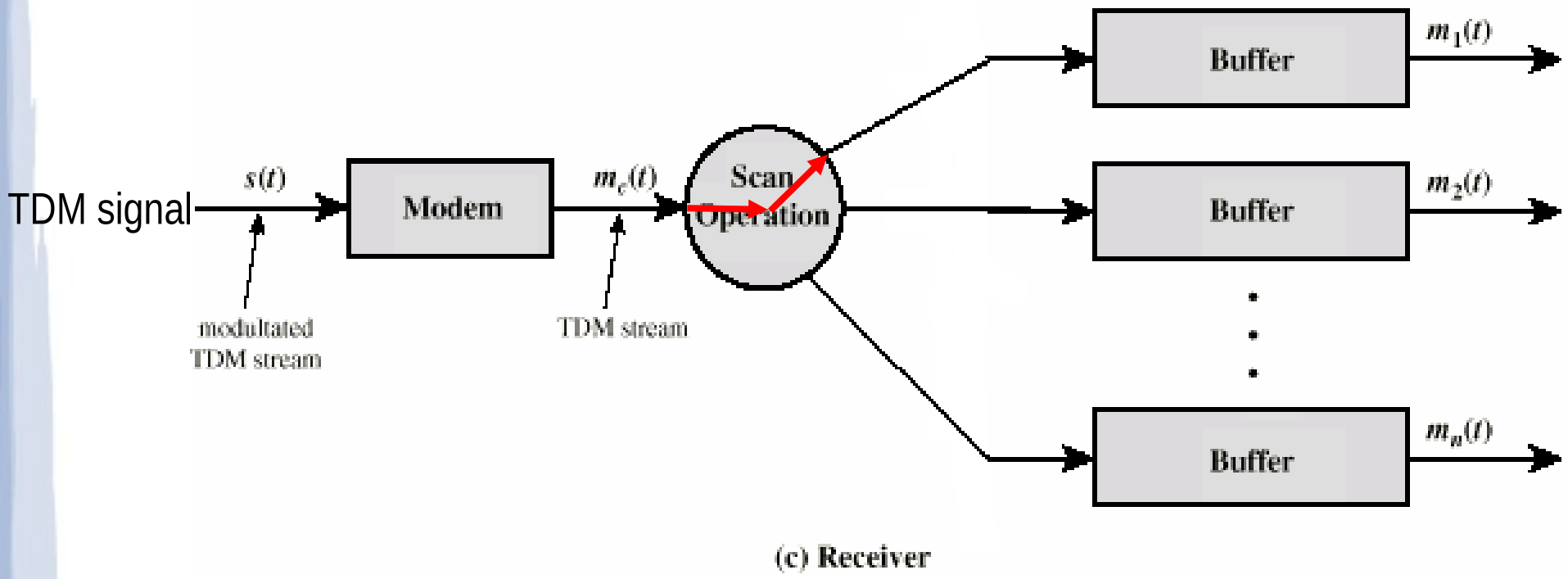
Scanning and link data rate: high enough to prevent channel buffers overflowing



T Should be enough to empty a channel buffer



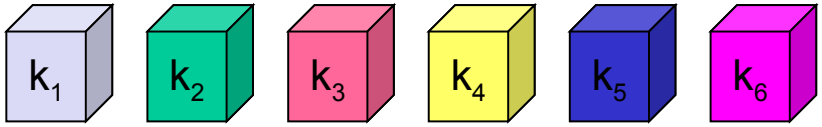
TDM System – Receiver



(c) Receiver

Code Division Multiplexing

Each channel has a unique code



All channels use the same spectrum at the same time

Advantages:

- bandwidth efficient
- no coordination and synchronization necessary
- good protection against interference and tapping

Disadvantages:

- lower user data rates
- more complex signal regeneration

Implemented using spread spectrum technology